

Field Emission Get-Away-Special Investigation (FEGI)

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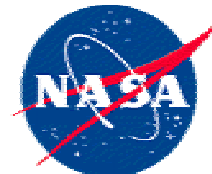
Pennsylvania State University

Jet Propulsion Laboratory

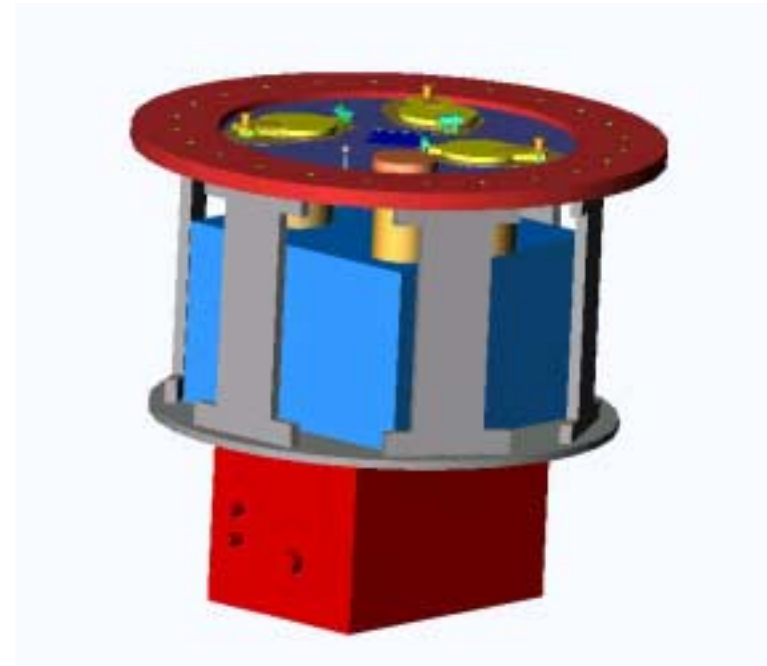
Air Force Academy



PENNSTATE



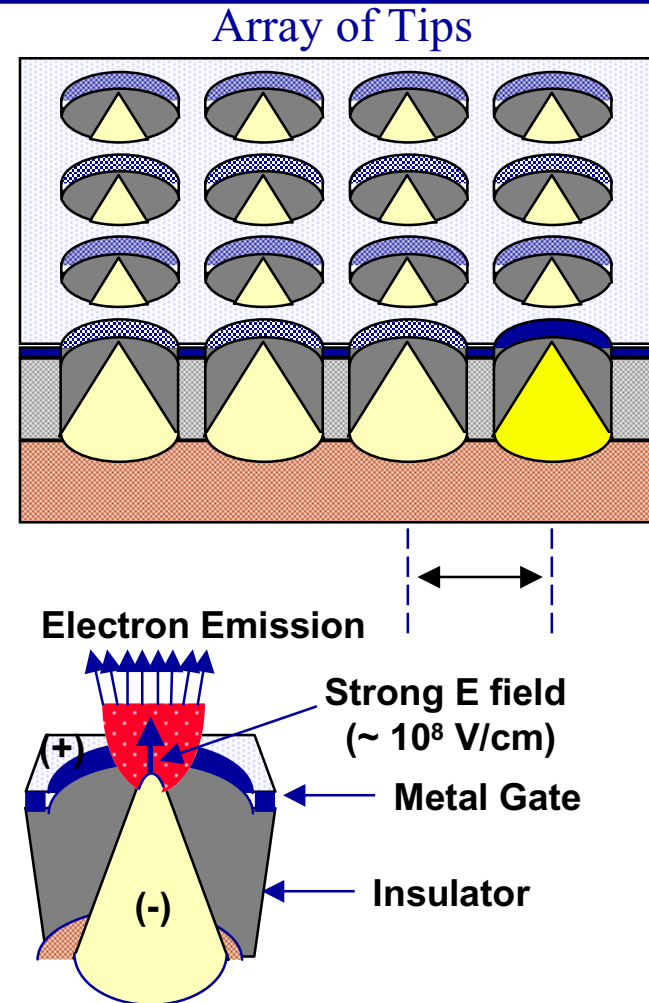
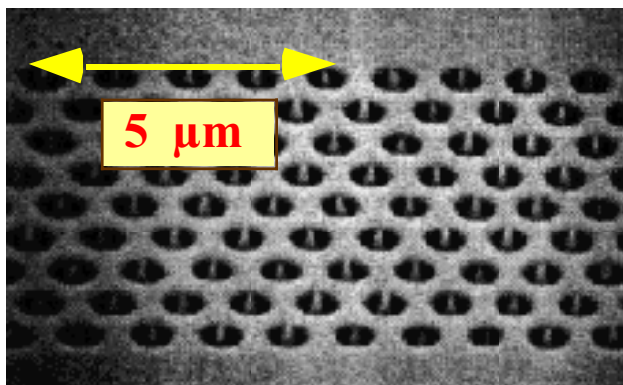
- FEA Concept
- Get Away Special (GAS)
- FEA Project Outline
 - Requirements
 - Implementation
 - System Architecture
- Student Involvement



FEA Concept/Physics



- Cold Cathode Electron Emission
 - No gas sources as with a plasma contactor
 - No heaters
- Bias voltage between gate and tip pair (50-100V)
- Each tip gets $\sim 1 \mu\text{A}$ current, arrays capable of A/cm^2
- Low Power, inexpensive

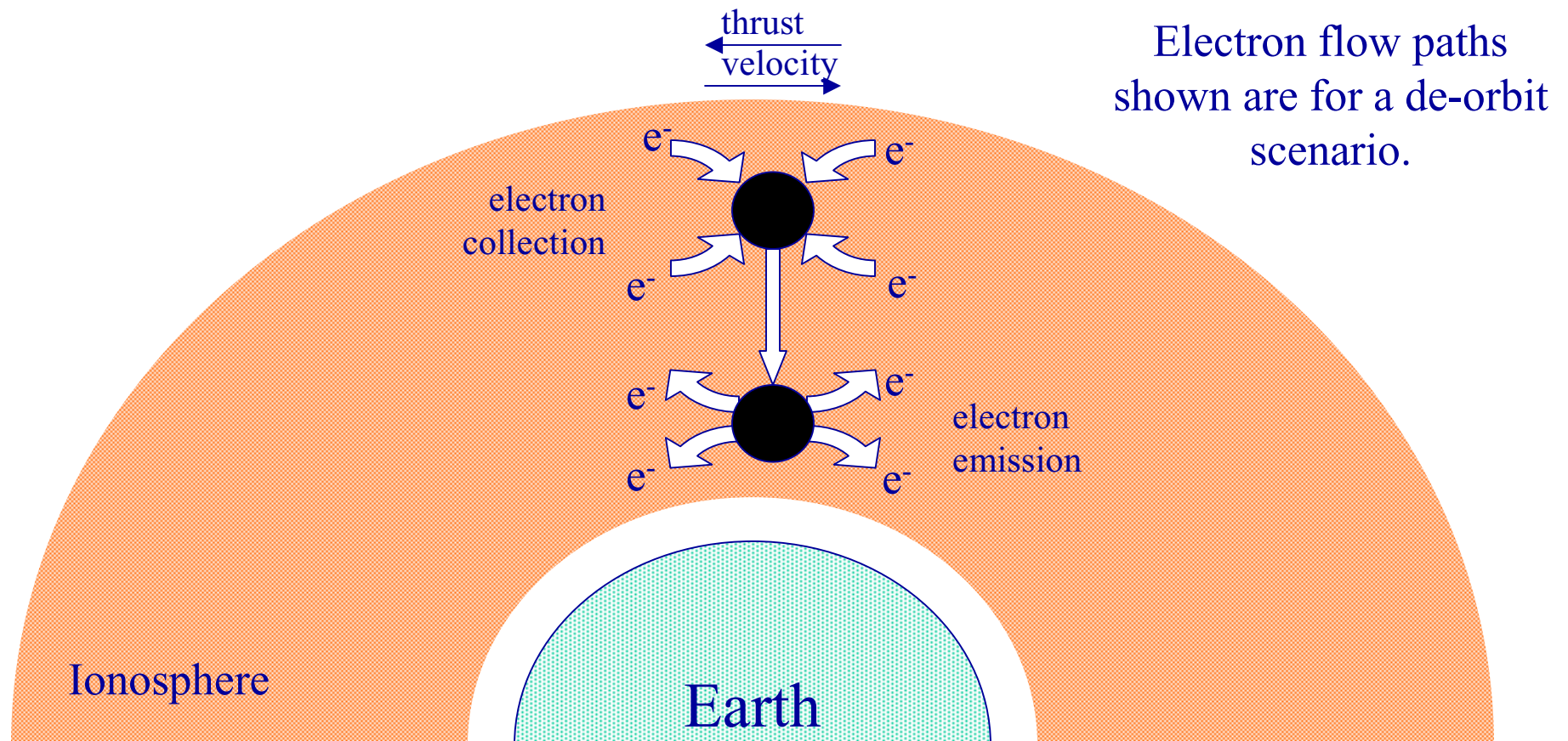


Tip Radius, $< 100 \text{ \AA}$
Tip Density, $10^6 \text{ tips}/\text{cm}^2$

Electrodynamic Tether Propulsion



Electrons emitted at the lower spacecraft diffuse into the ionosphere. Other electrons are collected at the upper spacecraft.



Why the shuttle?



- Advantages of the shuttle
 - Large electron collection surfaces (engine bells)
 - Eliminates system charging (just like a tether)
 - LEO environment
 - Return of payload, reusability
 - Analyze contamination effects
 - Analyze degradation (AO, etc.)
- Get Away Special (G-187)
 - Part of small shuttle payload program
 - Standard support (GSFC, Wallops)



Mission Requirements



- Mission Statement
 - To evaluate and demonstrate reliable cold cathode electron emission in a spacecraft environment.
- Driving Questions
 - What handling procedures are required to protect FEA devices from pre-launch to orbit?
 - What procedure should be used to most reliably initiate and maintain FEA operation on orbit?
 - What environmental and spacecraft conditions affect performance?

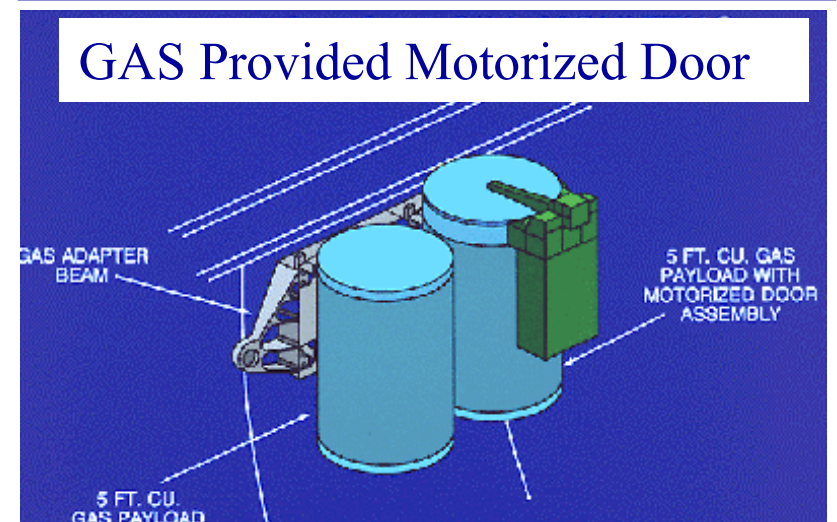
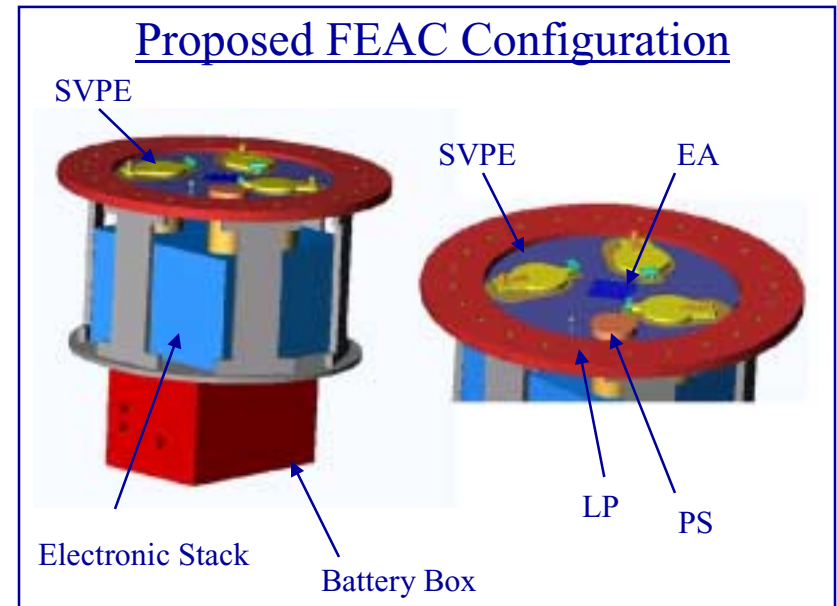
Required Measurements/Information

- Operational Capabilities
 - Up to +/- 1000V gate and/or tip bias capability, both DC and pulse mode.
 - Bias gate and tip together for electron bombardment cleaning
 - Transient bias contaminant clearing capability
- FEA Monitoring Measurements
 - Gate and tip potential
 - Gate and tip current
 - Return currents and energy of electrons to faceplate
- Environmental data
 - Neutral pressure
 - Plasma density and temperature near emitters
 - Magnetic field
 - Spacecraft effluents (shuttle water dump, etc.)

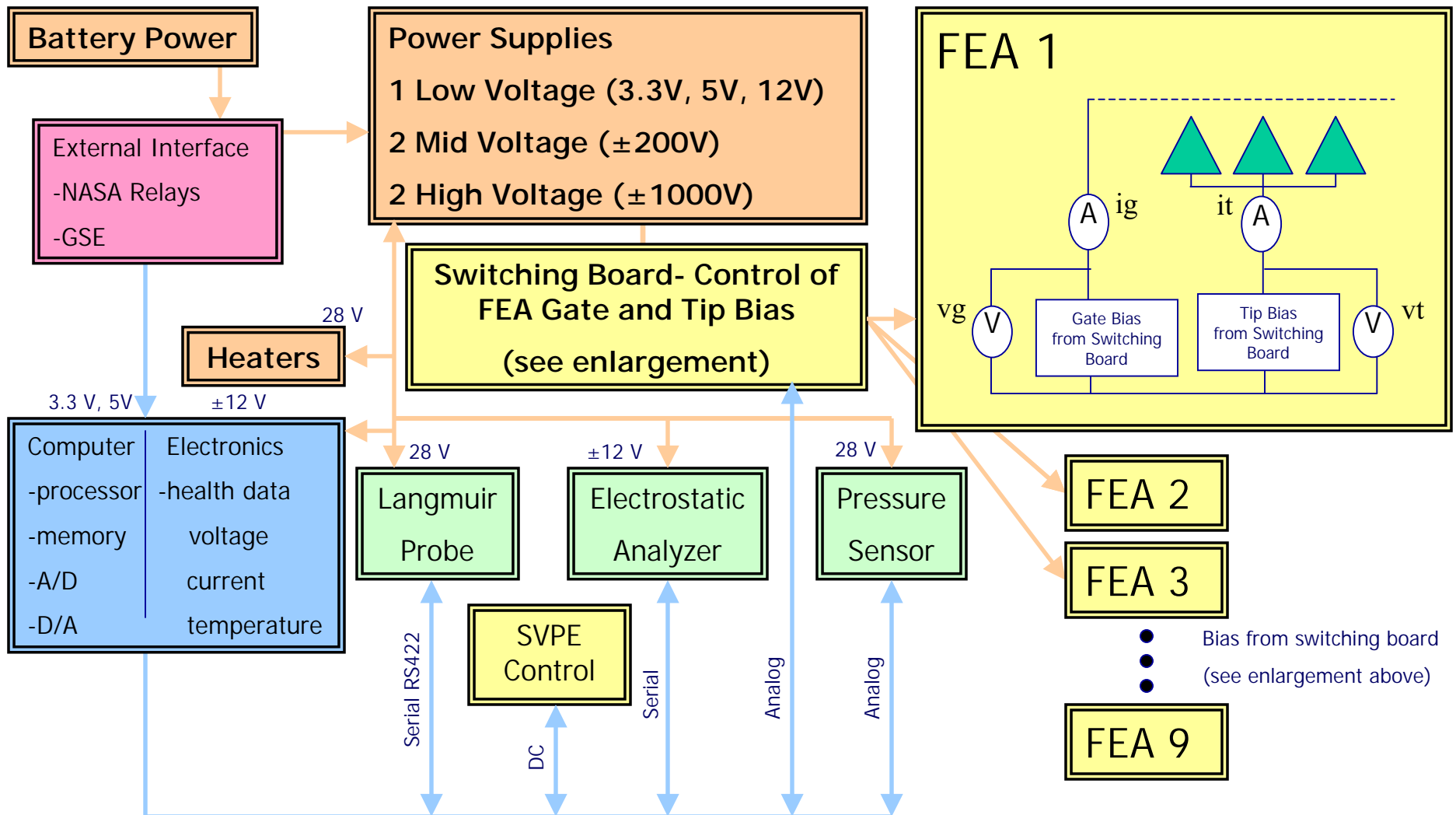
Implementation



- FEAs, 9 devices in 3 separate small vacuum protective enclosures (SVPEs)
 - Redundancy
 - Test multiple FEA designs
 - Provide different exposure times and/or cleaning protocols to identical devices
- Environmental Measurements
 - Langmuir probe (LP)
 - Electrostatic analyzer (EA)
 - Pressure sensor (PS)
- Support Equipment
 - On-board automated experiment control and data storage
 - Custom variable power supplies
- Utilize shuttle data stream
 - orbital position, orientation (ram/wake), thruster, FES, and water dumps, etc.



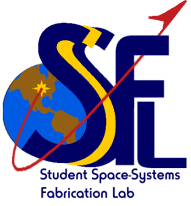
Block Diagram



Top-Level Mission Timeline



- Brief thermionic emission at beginning
 - High reliability
 - Baseline of emission capability and environmental interaction
- FEA cathodes (e.g. Spindt devices)
 - Baseline FEA technology (UofM/JPL experience)
 - Variety of biases, cleaning procedures, etc.
 - One continuously running for long term tests
- Other FEA technologies
- Combinations of emitters simultaneously



System Architecture



- Payload
 - Electron emitters (FEA, thermionic)
 - Environmental instrumentation (pressure, LP, MESA)
- Power & Electrical
 - Power distribution system for payload and computer
 - Experiment measurements of voltages and currents
 - Housekeeping measurements of voltages, currents, and temperatures
- Command & Data Handling
 - Experiment control
 - Data storage
- Structures
 - Mechanical
 - Thermal
 - Safety

FEGI Payload



- FEA
 - Heatwave Labs thermionic cathode
 - SRI Spindt-type cathodes, Michigan Si-tip cathodes
 - Developing technologies
 - MCNC, SPEEDG, carbon nanotubes, diamond or BN tip
- Electrostatic analyzer (MESA-U.S. Air Force)
 - Plasma potential relative to Shuttle ground
 - Return electron energy
- Langmuir probe (UM)
 - Plasma density and temperature
 - Plasma potential relative to Shuttle ground
- Pressure sensor (PSU)
 - Neutral pressure

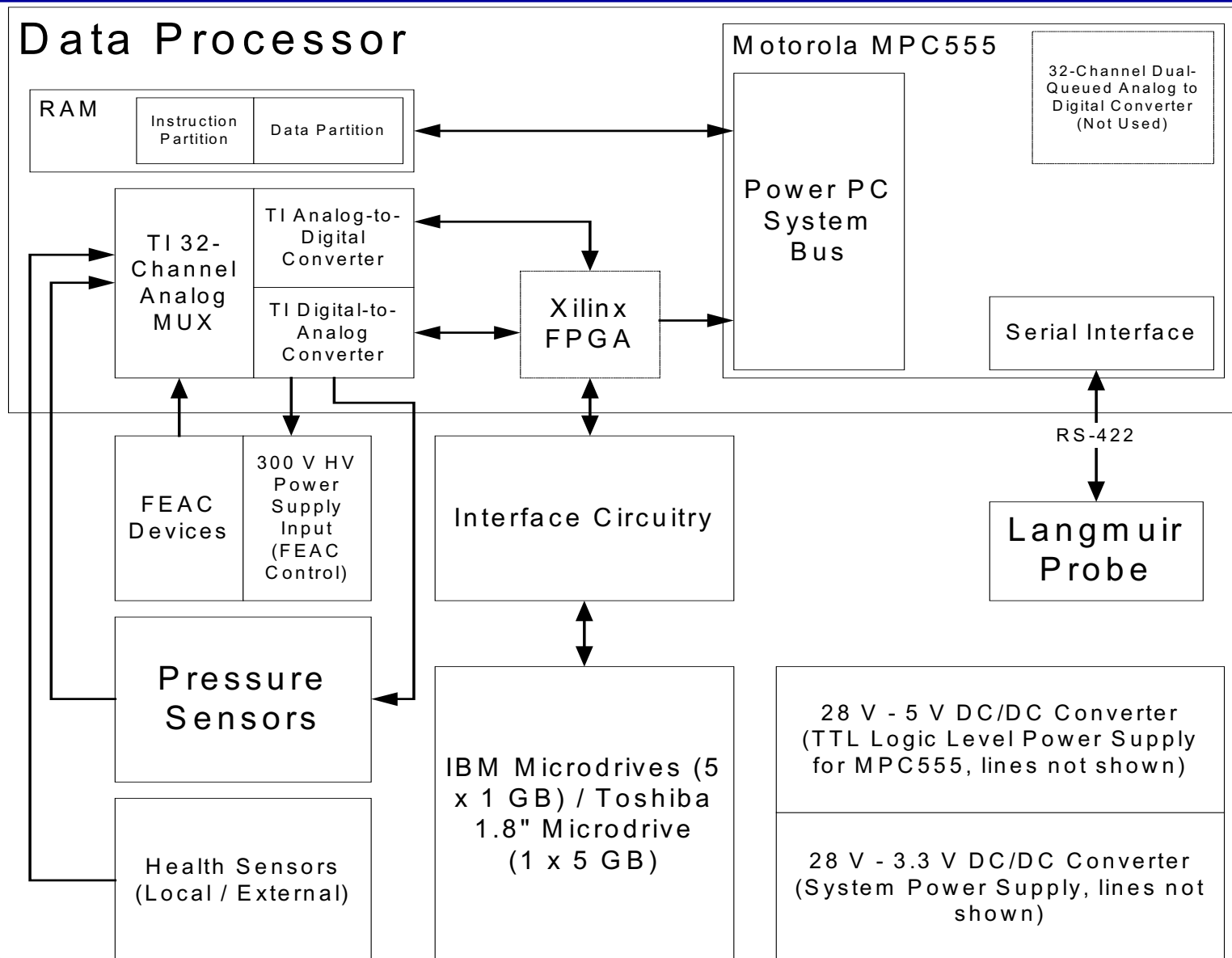
- Power distribution system
 - NASA interface
 - Battery box
 - Voltage Converters
- FEA biasing
 - Variable up to +/- 1000 V DC, 5V resolution
- Health and data measurements
 - Voltage
 - Current
 - Temperature
- Heaters

Command & Data Handling

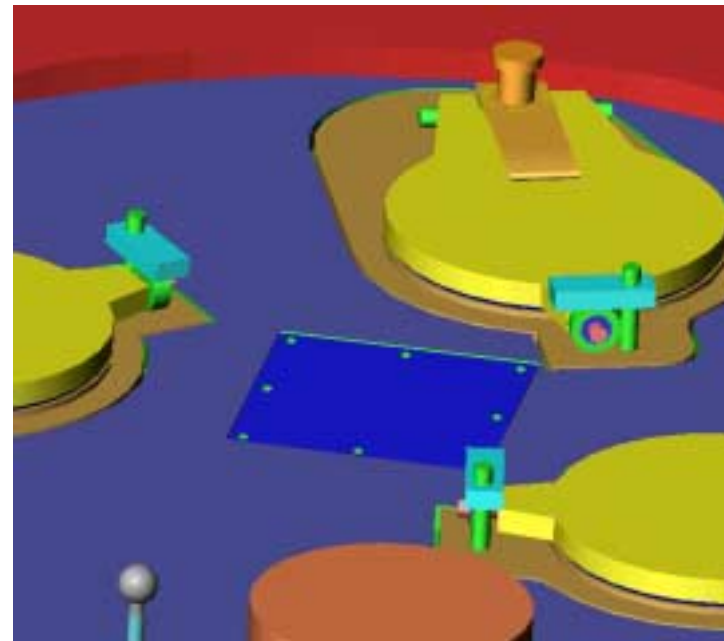


- Processing
 - Motorola MPC555 Microcontroller / PowerPC architecture
 - Xilinx FPGA to handle custom interface work
 - Maximum 8kHz burst (200 B samples) over system bus
- Data storage
 - IBM microdrive (5x1 GB)/ Toshiba 1.8" (5 GB)

C&DH Block Diagram



- Structural design
 - Framework
 - Experiment faceplate
 - Small Vacuum Protective Enclosures (SVPE)
 - Testing (structural and vibrations)
- Thermal
 - Nodal analysis
 - Heater requirements
- Safety
 - Pressure vessels
 - Fracture Control
 - Containment





Student Involvement



- Multi-university collaboration
 - University of Michigan
 - Penn State University
 - Air Force Academy
- Student Space System Fabrication Lab (S3FL)
 - Flight and prototyping labs providing students with hands-on experience
 - Graduate and Undergraduate Students
 - Aero, EE, CompE, ME, IOE, AOSS, Engineering Physics
- Faculty and Staff Engineering Mentorship
 - Faculty Principal Investigator
 - Engineering mentors from Space Physics Research Laboratory (SPRL)
 - Faculty Technology Advisors

Conclusion



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